Distributed, multiplatform high fidelity human patient simulation environment: a global-range simulation-based medical learning and training network

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Abstract: Simulation offers the most efficient adjunct in education and 'refresher' training of medical personnel. However, simulation devices and facilities are expensive and the combination of cost, distance from the training centres, and professional constraints prevent medical personnel in rural and remote regions from simulation-based training. We have demonstrated that these barriers can be overcome by the already developed distance simulation methods. However, whenever High Fidelity Patient Simulators are used in a multi-unit training environment (e.g., mass casualties) the problems of simulator incompatibility may introduce major problems in the orchestration and control of the simulated events. The paper discusses problems of international large scale 'just-in-time' training, and the initial solutions to simulation-based preparation of medical personnel using multiple simulators simulator sites separated by ultra-long distances.

Keywords: disaster medicine; distance learning; distributed simulation; EMS; first responders; high fidelity patient simulators; internet; medical education; medical readiness; medical simulation; simulation.

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1 Education and training in medicine – the never ending need

The past 50 years witnessed probably the most explosive growth of medical knowledge in the history of medicine (Kegley, 2002; Porter, 1997). New discoveries in pharmacology, molecular biology, neuroscience or reproductive biology, to mention just a few disciplines, were accompanied by similarly dynamic developments in medical practice – new diagnostic instrumentation, new surgical techniques and treatment modalities. Improved understanding of the process of disease combined with a revitalised interest in preventive medicine resulted in new, often international, treatment guidelines while the emergence of new threats imposed further changes in the practice of healthcare. Unsurprisingly, the issue of lifelong medical learning rose to unprecedented prominence and intensifying exploration of the means to improve the efficiency of medical education and postgraduate training (Billingham et al., 2002; Colliver, 2002; Hans, 2002). According to the Entrez-PubMed literature database, nearly 3000 papers on medical education were published in 2002 alone. Many of these papers describe highly innovative methods that frequently involve utilisation of very sophisticated technologies. Predictably, most advanced training techniques are employed at the major medical training centres (Harter et al., 2002; Leitch et al., 2002; Letterie, 2002). On the other hand, access to the continuous medical education (CME) remains to be problematic for practitioners in rural and remote regions of the globe (Booth and Lawrance, 2001; Davis and McCraken, 2002; Delaney et al., 2002; Hoyal, 1999). Isolation, inconsistent quality of training programmes and variation in the allocation of training resources are among the principal issues that need to be addressed to produce measurable changes (Rourke and Rourke, 1995).

The emergence of new medical threats such as bioterrorism (Darling et al., 2002) poses an additional challenge in educating large numbers of pre-hospital and emergency room personnel necessary to ensure maximum level of readiness (Brocato and Miller, 2002; Cunha, 2002; Darling et al., 2002; Willaims, 2001). The fact that medical professionals who typically do not participate in EMS operations may have an active role in interventions associated or following an act of bioterrorism (Fahlgren and Drenkard, 2002) is a clear indicator that the required training must account for the existing differences in baseline knowledge. Furthermore, despite a potentially very large number of recipients and their nationwide or even global distribution, the required training programmes must be based on standardised curricula and be conducted at a consistently high quality level to fulfil their mission of developing and sustaining adequate preparedness against emerging threats of bioterorism or mass casualty events (Baker, 1999; George et al., 2002; Guay, 2002; Peleg et al., 2002; Rubinstein et al., 2002). In summary, even a perfunctory review of the existing literature will clearly indicate the persistent need for continuous education and training of both pre-hospital and hospital personnel (Cowley et al., 1984; Doyle, 1990; Watterson and Thomas, 1992) and the significant role of federal, state, local and non-governmental agencies in developing robust tools and systems that will be sufficient to provide both continuous and 'just-in-time' medical training (Koplan, 2001; Lalich, 2002; Levi et al., 2002).

2 The prehospital training challenge

Rapid growth of medical knowledge and its almost immediate translation into changes in practice combined with increasing specialisation (Donini-Lenhoff and Hedrick, 2000; Guleson, 2001; Schroeder, 2002) and a multidisciplinary approach to the treatment of disease (Buckingham and Adams, 2000; Connor et al., 2002; Hazard, 1994; Scheen et al., 2001; Schriefer et al., 2000), requires a very wide range of specialised postgraduate education at all levels of medical competence. Problems ranging from communication and definition of professional identities and roles within the medical management team (Burd et al., 2002; Cooper et al., 2002; Lingard et al., 2002; Sherwood et al., 2002), through procedure difficulties (Bair et al., 2002; Lefrancois and Dufour, 2002; Ruppert et al., 1999), missed or wrong diagnoses (De Lorenzo, 1993; Herlitz et al., 2002; Linn et al., 1997; Trzeciak et al., 2002), to errors in medical command of EMS (Emergency Medical Services) operations or inadequacy of pre-hospital provider training (Chiara et al., 2002; Cupera et al., 2002; Holliman et al., 1992) have been described. The majority of adverse incidents appear to be related to inadequate knowledge and/or insufficient training seen as much at the pre-hospital as at the in-hospital environments (Bair et al., 2002; Cone and Murray, 2002; Hodgetts et al., 2002; Trzeciak et al., 2002). One of the predominating issues that await rapid solutions is that of inadequate training of non-specialist healthcare workers, particularly in the rural areas, in adult and pediatric emergency and trauma medicine (Cone and Murray, 2002; Dick et al., 2002a,b; Hodgetts et al., 2002; Johnston et al., 2001; Luiz et al., 1997; Simon and Sullivan, 1996; Simon et al., 1994; Somers et al., 1999; Tollhurst et al., 1999; Tye et al., 1978) and in surgery (Girgis et al., 2001; Kelly, 1998; Mil'kov et al., 1988; Reid et al., 1999; Sohier et al., 1999).

Clinical and procedural errors resulting from training deficiencies at the first responder/paramedic level are common (Cayten et al., 1978; Linder et al., 2001). The adverse effects of less than optimal teamwork caused by poor team training (Williams et al., 1999), substandard mastery of essential (even basic) resuscitation diagnostic skills and procedures (Bradley et al., 1998; Coontz and Gratton, 2002; Eberle et al., 1996; Hubble et al., 2000; Liberman et al., 1999), and unreliability in the delivery of such common services as advanced cardiac life support (Peacock et al., 1985) have been well documented. Even more problematic are the substantial inadequacies in pediatric resuscitation skills resulting from inadequate training and infrequent exposure to pediatric emergencies (Seidel, 1986; Seidel et al., 1991; Su et al., 2000; West, 2000). The intense need for continuous training is emphasised by the recently reported lack of reliability in performance rating during EMT (Emergency medical Technician) licensing examinations (Snyder and Smit, 1998) – a failure that allows operational entry of personnel with less-than-optimal knowledge and skills. Inadequate entry-level preparation combined with the demonstrated skills decay (Su et al., 2000; West, 2000; Zautcke et al., 1987) provide a further argument for the vigorous maintenance of clinical competence through the process of lifelong learning among all healthcare professionals (Elkin and Gorman, 2002; El-Tabgy and Rupp, 2002; Farti et al., 1996; Graber et al., 2002; Hall and Nowels, 2000; Kanz et al., 2002; Orient et al., 1982; Sultz et al., 1984; Taylor and Kiser, 1998; Wise et al., 1994).

Trivial in comparison to often life/death repercussions of medical errors, the costs that accompany each incident of faulty patient management constitute another significant motive to provide adequate training. It is estimated that the average price of a resuscitation attempt at a British hospital reaches approximately £1000–2000 (Gage et al., 2002). In the USA, the expenditure for the resuscitation following out-of-hospital cardiopulmonary arrest may reach \$6000–10,000 (Ronco et al., 1995; Rosemurgy et al., 1993). Clearly, any error that results in serious aggravation of the presenting complaint will automatically increase the final cost of care by making it more complex and more resource-demanding (Zack et al., 2002). Thus, while the argument of ‘I am certified’ may still be heard, the wealth of existing data on errors committed by ‘certified’ personnel indicate that the presence of certification may offer false security in one’s own medical prowess. The real cost of such (possibly unwarranted) certitude may, indeed, be quite extreme both in terms of the outcome and in the related expenditure.

3 The existing training methods

Presently, healthcare education is conducted in a manner that, despite a host of advances in didactic technology, has not changed significantly during the recorded history of medicine (Porter, 1997). In the broadest terms, training of healthcare professionals is conducted either as a totally passive assimilation of the existing body of knowledge such as books (Fritsche et al., 2002; Lancaster et al., 2002) or lectures (Murphy et al., 1995; Rowke, 1994), or through an active hands-on approach. The latter may involve either the combination of passive and active methods or the hands-on methods alone (Loutfi et al., 1995; Moseley et al., 2002; Sanson-Fisher et al., 2002). Significantly, while it is often claimed that electronic dissemination of medical knowledge provides ‘interactivity’, many existing platforms represent nothing but technologically advanced forms of traditional, essentially passive, training based on old didactic principles [e.g. (De Leo et al., 2002; Dornan et al., 2002; Gold et al., 2002)]. The advantage of the effective use of information technology in the didactic e-training packages rests with the ease of access to the appropriate sources of information, rapid cross-referencing of information and the supporting data, and the ability to organise information derived from various resources into easily catalogued logical units that assist in the subsequent assimilation and solidification/retention of the acquired knowledge.

Rapid growth of internet connectivity in the technologically advanced countries is associated with the most important attribute of electronic healthcare knowledge dissemination – rapid erosion of distance as the main obstacle in accessing postgraduate professional education among healthcare personnel in rural and remote regions of the world (Von Lubitz et al., 2002). The existing internet/web-based medical training and/or consultation programmes cover a wide range of topics (Casebeer et al., 2002; Fieschi et al., 2002; Greengold, 2002; Mann and Colven, 2002; Poyner et al., 2002; Tichon, 2002), satisfy almost every need for specialised knowledge, and, with the increasing sophistication of the existing models, may involve a large variety of approaches spanning from e-mail exchange (Deodhar, 2002; Marshall et al., 2001; Pastuszak and Rodowicz, 2002) to videoconferencing and multimedia offerings (Allen et al., 2002a,b; Davis and McCroaen, 2002; Haythornthwhite, 2002; Marshall et al., 2001; Pastuszak and Rodowicz, 2002). The main disadvantage of didactic distance learning is its essentially static nature that may not reflect the dynamism of medicine, particularly in the context of specialties like emergency/trauma and military medicine, or surgery (Von Lubitz et al., 2000a). The existence of inaccurate, obsolete, or incomplete content of many medical information sites provides another major problem that continues to affect the overall quality of Internet-based learning resources (Lamminen et al., 2002; van Lubitz et al., 2002).

Hands-on training based on the trainee–patient contact, while highly effective in the development of the necessary clinical skills (Fay et al., 2001; Hicks, 2001), is also associated with a number of challenges (Girdler, 2001; Gonzalez and Mohl, 2002; Haponik et al., 2000; Mandavia et al., 2000; Robinson, 2002) and risks (Friedrich, 2002). In the past 80 years ,[1] the aviation community, where both training and operations are associated with many characteristics similar to the high-paced tempo of medical specialties such as emergency medicine, trauma medicine, or perioperative care, used simulators both to increase the efficiency of training and to minimise the dangers associated with it (Brannick et al., 1995; Knowles, 1967; Krebs et al., 1999; Ricard, 1995). Although the history of simulation in medicine is significantly shorter, its importance in education and training, and the level of sophistication increase very rapidly (Bond and Spillane, 2002; Greenberg et al., 2002; Nagoshi, 2001; Shapiro and Morchi, 2002; Vardi et al., 2002). Presently, High Fidelity Patient Simulators (HFPS, previously known as Human Patient Simulators) serve as highly complex 'medical flight simulators' in a wide variety of training tasks. The use of HFPS units in hands-on training eliminates the risk factors associated with training on live patients, permits improvement of diagnostic skills by allowing practical understanding of the involved steps, hones medical team training (Kanter et al., 1990; Pittini et al., 2002; Small et al., 1999; Weller et al., 2003), and helps in punishment-free learning from errors (Garden et al., 2002; Jeanguiot, 2000; Mackenzie et al., 1996; Von Lubitz et al., 2000). Virtual reality simulation (Agazio et al., 2002; Graschew et al., 2002; Patterson, 2002; Seymour et al., 2002; Von Lubitz et al., 2000) represents technologically the most advanced level of medical simulation that is particularly suitable for training in surgical techniques (Seymour et al., 2002).

A rapidly increasing number of publications describe preeminent applicability of medical simulation in training of healthcare personnel (Byrne and Jones, 1997; Cosman et al., 2002; DeAnda and Gaba, 1990; Devitt et al., 2001; Fletcher, 1995; Gaba and DeAnda, 1988; Hotchkiss and Mendoza, 2001; Issenberg et al., 1999; Schwid et al., 2002; Spence, 1997; Watterson et al., 2000; Wong et al., 2002) across several specialties. In the majority of cases, studies of simulation efficacy have been performed in the setting of large training institutions that can easily supply the required significant fiscal resources for the acquisition of simulation equipment, and provide both space and personnel necessary for the successful operation of a simulation centre (Gordon and Pawlowski, 2002; Schaefer and Grenvik, 2001). Unsurprisingly, the typical target audience of simulation-based training consists of students and house officers (residents), associated with the institution owning the centre, who are already exposed to the substantial concentration of the pre-existing, albeit more traditional educational resources. In contrast, pre-hospital healthcare professionals, particularly in the rural and remote regions or in many of the Less Developed Countries (LDCs), are essentially excluded from the benefits of both didactic education provided by major academic training centres and from simulation-based training predominantly conducted at the very same centres. The problem is compounded even further by the site-bound nature of simulation-based training, the cost of attending such training, the ease of accessing the training site or the combination of all these factors (Von Lubitz et al., 2000). Paradoxically, economical and logistic issues prevent simulation technology from reaching the audiences where such technology may have a far greater impact than at the established centres of medical learning.

4 Simulation and medical training

Similarly to aviation, large-scale introduction of simulation-based medical training (Isenberg et al., 2001; Karnath et al., 2002) may result in significant progress towards reduction of diagnostic and procedural errors, improvement of confidence and preparedness and enhanced medical readiness (Hammond et al., 2002; Morgan and Cleave-Hogg, 2002; O'Donnell et al., 1998). While quantitative studies are needed to prove the translation of simulation-derived improvement into daily clinical practice, the data already available indicate that simulation may have a substantial and positive impact on the quality of training and clinical performance of individuals (Block et al., 2002; Forrest et al., 2002; King et al., 2000; Rosenblatt et al., 2002; Watterson et al., 2000; Weller et al., 2003) and medical teams (Halcomb et al., 2002; Murray and Foster, 2000), with the consequent improvement of patient safety (Fellander-Tsai et al., 2001; Gordon et al., 2001; Murray et al., 2002; Roll et al., 2002).

Our previous publications (Von Lubitz, 2002; Von Lubitz et al., 2000b, 2001) have extensively discussed the need for simulation-based training of medical personnel. The conceptual incompatibility of the existing training platforms ('solid' simulation devices such as High Fidelity Patient Simulators versus VR-based devices) has been successfully overcome by the creation of a 'medical flight simulator' (Von Lubitz et al., 2000a) in which a High Fidelity Patient Simulator (METI) has been incorporated as a centrepiece of a dynamic VR-rendered environment (CAVE). Other investigators using procedure training devices provided convincing evidence of the efficacy of training performed in VR environments (Agazio et al., 2002; Gallagher and Satava, 2002). Even more importantly, highly complex 'total VR' surgical training systems have been developed and tested during the past few years (Caudell et al., 2003) indicating the direction of the training trend at large centres of academic medicine.

The sophisticated High Fidelity Patient Simulators (HFPS) and less complex single-procedure simulators provide the less technically complex and more accessible medical training tools. While HFPS units are pre-eminently suitable to train personnel (Lary et al., 2003) in rapid diagnosis and management of complex emergency and trauma events, they are also sufficiently complex to require dedicated personnel and facilities support. Moreover, despite decreasing acquisition price (the phenomenon that also characterises VR environments,) the purchasing and operating costs are high (Morgan and Cleave-Hogg, 2001; Schaefer and Grenvik, 2001) and place simulation-based training beyond the means of smaller organisations (Von Lubitz et al., 2002). It is, however, likely that the expanded use of simulating devices in teaching pre-clinical subjects, use in non-traditional setting e.g., training of veterinarians (Modell et al., 2002), physiology education (Tan et al., 2002) or pharmacology [von Lubitz et al., unpublished] will significantly broaden their applicability across several disciplines and may spread the expenditure more evenly. Innovative operational framework of training centres (Gordon and Powlowski, 2002) may also help to reduce the immediate costs of access even further.

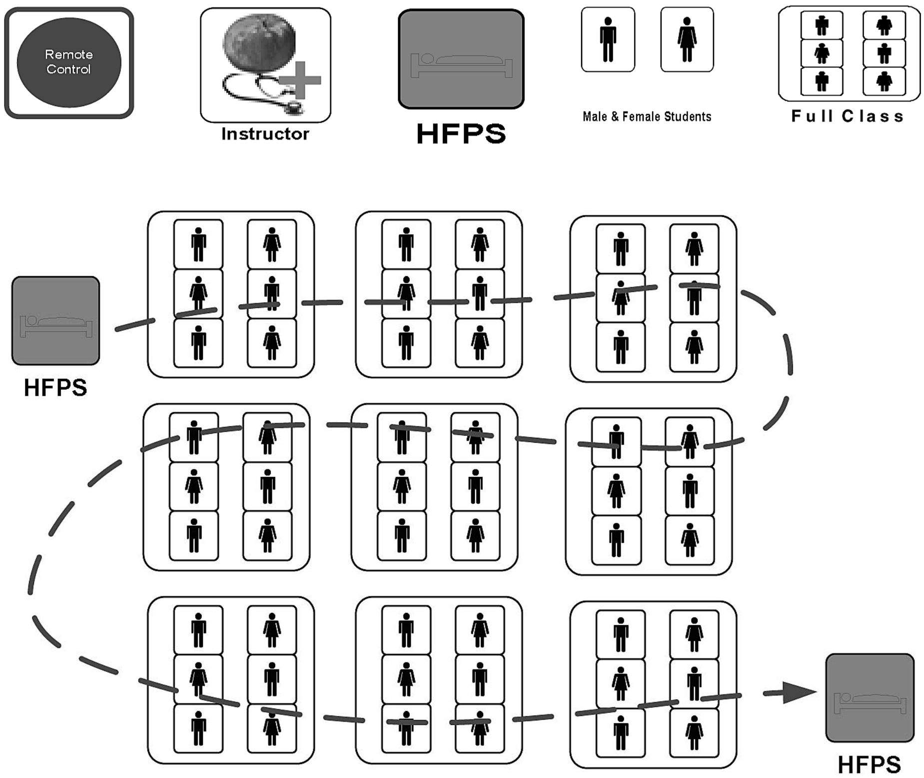
During the past 4 years we have proposed, developed and tested under routine operational conditions, a new approach intended to breach the tradition of stationary simulation centres, and make simulation-based medical training available to essentially anyone with an internet connection. The latter aspect is of particular importance in developing countries where even the most essential elements of medical training are faltering due to insufficient resources (Von Lubitz et al., 2002). The concept is based on the remote access to the central simulation facility and its HFPS machines from distant training sites located practically anywhere in the world and allows training under the guidance of a centrally located expert teacher. Despite its demonstrable usefulness (Treloar et al., 2001; Von Lubitz et al., 2003), the operational applicability of the concept was limited due to the problems in successful operation of more than a single HFPS unit. Yet, the need for a coordinated, simultaneous operation of several HFPS devices (either as a simulator LAN or WAN) is essential when training involves mass casualties, or when the machines used as the constituents of the training federation (Proctor and Creech, 2001) are the product of more than one manufacturer.

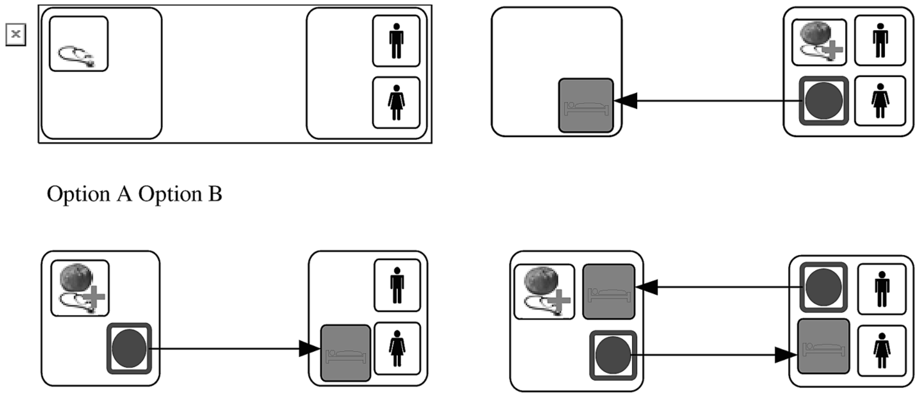
5 Simulation-based distributed medical training

In order to circumvent the obstacles preventing large-scale access to simulation-based training, we have developed and operationally tested a model for distributed simulation-based training targeted at widely dispersed, large numbers of medical personnel (Figure 1). The Med-ASP model combines the principles of Distributed Interactive Simulation (DIS) and of the Application Service Provider (ASP; see Figure 1 and (Proctor and Creech, 2001; Von Lubitz, 2002; Von Lubitz et al., 2000c)). Practical implementation of the Med-ASP concept allows execution of highly realistic training in the often complex and stress-filled environment of field emergency and trauma medicine and obviates the need for the trainees to leave their physical location that may be separated by thousands of miles from the simulation facility (Treloar et al., 2001; Von Lubitz et al., 2000c, 2003, 2004). The additional advantage of the model is its pre-eminent suitability for real-time dissemination of world-class training expertise in the form of practical 'patient demonstrations' rather than the commonly encountered didactic format of a theoretical lecture. Consequently, learner audiences in rural and remote regions or in the economically disadvantaged countries who, hitherto, had significant difficulties in accessing arguably the most sophisticated form of medical learning can readily benefit from both advanced training technology and expertise (Von Lubitz et al., 2002). Moreover, customised services may be provided readily and, essentially, on demand. The demonstrated ease of such access

(Von Lubitz, 2002; Von Lubitz et al., 2000c, 2003, 2004) is of special significance for EMS and military healthcare providers, particularly in situations of increased need for 'just-in-time' training of a large number of personnel deployed to several geographically dispersed sites (Von Lubitz et al., 2000a) as seen during bioterrorist threats, military conflicts, or large scale rescue operations (Von Lubitz et al., 2004).

Figure 1 Classical use of HFPS devices is based either on the exposure of groups of trainees to the stationary simulator located at the training centre or rotation of the device through a series of predetermined distant facilities. In either case, the use of these expensive devices is suboptimal, the exposure of individual trainees to the simulator is infrequent, and the cost is potentially high. Moreover, exposure to the stationary simulator limits the number of the trainees exposed to this type of education (limited number of time units available) while rotation of the simulator through a number of sites may impair the quality of training due to the limited time the device can stay at each individual location.

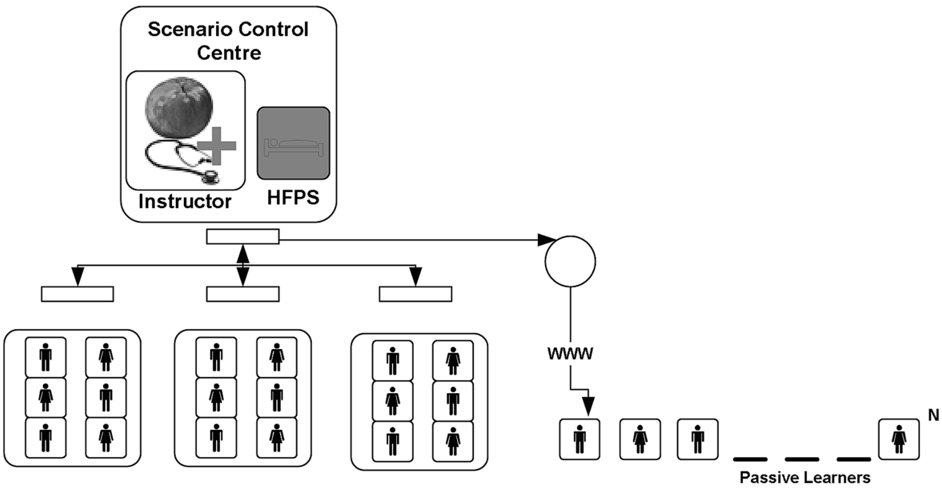




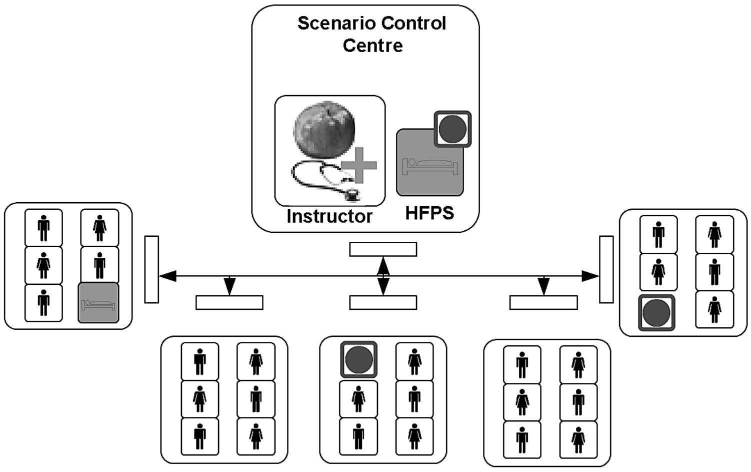
Option A Option B

Option C Option D

Distant simulation-based education and training can be conducted using several configurations in the relationship between the simulator, control centre, and the trainees shown as Options A–D. Option D shows the environment where multiple dispersed simulators are operated by a single instructor commanding several control centres and several simulation units, often by different manufacturers. The configuration provides high operational flexibility but is technically complex. It is also ideal for simultaneous training of large numbers of personnel in dealing with a common threat that may require highly uniform, algorhythm-based responses (e.g., dealing with victims of bioterrorism, combat injuries, etc.).



Advanced Distributed Learning model. The training expert at the scenario control centre controls the simulator located at the centre and remains in visual and audio contact with the active remote sites. The instructor provides remote training either to all groups or selects one (in this case the middle) to act as the ‘active site’ that retains control of the simulating device. The instructor can switch at will among the sites and designate either the site or the individual trainee(s) there as the ‘scenario lead’. The considerable level of flexibility allows the training expert to engage the trainees as active participants interacting with the simulator rather than interact with a passive audience expecting the instructor to conduct a didactic demonstration.



The most sophisticated form of distance simulation-based medical training occurs when several simulator and control centers are connected into a training grid under the control of the central scenario-controlling facility. The concept requires highly agile telecommunication platforms eliminating time lags, video-sound discrepancies, simulator response delays, etc. On the other hand, it is at this level of sophistication that additional simulation modalities of even greater technical sophistication (e.g., virtual reality) can be introduced creating highly complex 'distance-based training suites' that combine training of large, multidisciplinary medical teams and preparation for interaction among such teams.

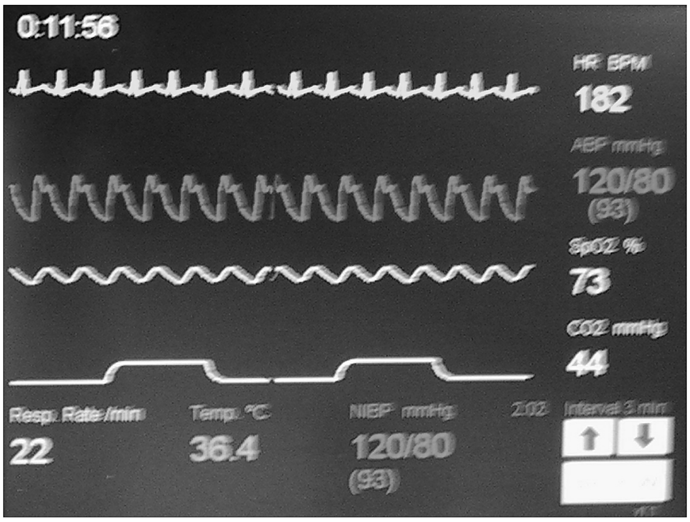
6 Multi-platform environment

When several dispersed HFPS units are either controlled from a central training facility or accessed by the remote learners, the only means to ensure uniformity of training is to assure full compatibility of both physical and operational characteristics of the simulation devices. This aspect becomes critical when the training centre has either the overriding remote control of all distributed HPFS units, or when the centre serves as the 'expertise headquarters' (Von Lubitz, 2002; Von Lubitz et al., 2000a,c, 2003, 2004) during simultaneous, real-time training of large numbers of dispersed learners, e.g., in multi-simulator training of international medical intervention teams (e.g., just-in-time preparation for mass casualties caused by acts of terrorism, natural disasters, etc., e.g. (Fahlgren and Drenkard, 2002; Rubinstein et al., 2002).

While the two principal HFPS systems in existence (Laerdal and METI, Figure 2) have practically identical anatomical features and generate a very similar profile of training-relevant output, the conceptual basis of their software/hardware interaction differs significantly. As a result of these differences, combining both systems into a unified, remotely accessible training environment poses practical difficulties.

Figure 2a Laerdal SimMan HFPS configured to operate as a platform for training management of severe trauma. The simulator is moulaged to represent significant burns to the chest and arm, facial penetrating injuries and avulsions, and open abdominal injuries with avulsed intestines. Patients of this type would be encountered following major traffic accidents, industrial explosions, or combat. Training in the field management of grave traumatic injuries at the pre-hospital level is greatly facilitated when HFPS units are used. Importantly, appropriately conducted simulation introduces the realism and stress of complex medical environments that cannot be reproduced in more traditional training settings. The figure clearly emphasises the pre-eminent suitability of simulation for just-in-time training.

Figure 2b Vital signs monitor screen showing physiological responses of the patient shown in Figure 2a who has now reached the decompensated shock stage. Unless immediate, vigorous, and competent action is initiated in the field, death before reaching a hospital with expertise in the treatment of multiple trauma is the most likely outcome.



In the simplest setting of multiple simulators, all devices can be easily slaved to the same high speed CPU/high RAM control computer located at the central training facility. While this solution permits simultaneous or individual remote operation of the federated HFPS units by the *same manufacturer*, centralised and simultaneous remote control of dispersed, collaborating simulators built by *different manufactures* is severely impeded by software incompatibility of the machines.

From the medical point of view, voice commands given by the remote trainee to the personnel at the simulator host site (the central training facility) are the most realistic. The distance separating the remote trainee from the HFPS notwithstanding, this approach approximates real-life actions of a medical team. The use of separate computers dedicated solely to the control of federated HFPS units by the same manufacturer provides a more automated solution. Yet, in a fast-paced environment of a multi-patient scenario, such control, particularly if remotely executed by the trainees with little or no background in computer operations, may become very cumbersome. In trying to overcome the need for simultaneous machine control, the trainees' attention will rapidly shift from the main subject (medical training) to the frantic attempts at mastering unfamiliar technology. Clearly, the essential attribute of simulation – situational realism – will deteriorate and decrease effectiveness of training.

Simulator-bridging software that automatically translates commands given from the control interface of one system into the commands that are understood by the simulator of a different and otherwise incompatible brand is the most effective solution to multi-HFPS environments. It is also technically the most complex since, in the absence of commercially available products, the software bridge must be developed as a private venture at the user's facility. Thus, from the technical and fiscal point of view, the most suitable placement of the software bridge is at the central (hub) control facility at which all signal processing takes place. The latter solution is identical to the concept of Medical Application Software Provider (Med-ASP) that we proposed in one of our earlier publications (Lary et al., 2003).

Implementation of the ASP concept simplifies signal traffic and, by providing more effective processing, eliminates the annoying time lags that may render distance-based simulation training exceedingly unrealistic. The Med-ASP concept assures that only the meaningful commands are passed within the simulator federation and also that exchange occurs at the maximum speed allowed by the available bandwidth.

7 Practical operations

For practical purposes, testing of the distributed multi-simulator training concept was conducted using two simulators. During operations between Ann Arbor, MI, USA and Laval, France two SimMan (Laerdal) HFPS units were used. One HFPS was located at the training centre of MedSMART, Inc. in Ann Arbor while the second simulator was placed at the city exposition hall in Laval, France. The participants in Ann Arbor could interact with the conference participants (trainees) in Laval over a two-way real-time interactive videoconference, with full screen, full motion video and high-quality audio. Similar principles were used during subsequent series of training exercises performed between MedSMART Training facility in Ann Arbor, MI, Alpena (MI, USA) Medical Readiness Training Center of the Air National Guard, and the Training Center of Telecom

Italia in L'Aquila, Italy. However, in the latter case two HFPS units manufactured by Laerdal, Inc. and METI, Inc. were used. Laerdal units were stationed in Ann Arbor, the METI device in Alpena, and the trainees at the Italian site had only the remote access to either machine. To eliminate concerns posed by opening military network at Alpena to civilian telecommunication traffic a dedicated high-speed LAN was used to link simulators placed at physically separated locations (approximately 250 km apart). In either case, real-time interactivity and simulator control were accomplished using high-end videoconferencing systems at all locations, with an ADSL internet connection bridging all sites. An ADSL internet connection was selected to test the performance of the relatively unsophisticated telecommunication link that would be relatively common at technically less advanced locations yet offering both the simplicity of the set-up and an acceptable stability during the transatlantic operations. It must be emphasised, however, that HFPS remote control can be implemented over any type of wide area link, including a standard telephone connection, dedicated private line, or via the internet (Treloar et al., 2001; Von Lubitz et al., 2000a, 2001, 2003, 2004 and the section on training for First Responders at www.med-smart.org).

One of the critical factors during training was the dependence of the overall quality of sound and image on the bandwidth (speed) and latency (delay) of the internet connection. A minimum of 128 kilobits per second sustained transfer rate is required for real-time videoconferencing. With round-trip latencies exceeding 200 ms, delays would be noticeable (similar to the delay encountered over a satellite telephone call.) Constant measurement of latencies and bandwidth variation between Laval and Ann Arbor indicated a relatively low average latency (below 100 ms round trip) with sufficient average bandwidth (sustained >300 kilobits) that was adequate to prevent imagery delays (pixellation). Transmission stability allowed us to conduct contiguous, and essentially uninterrupted, sessions lasting 1–4 h each.

During training, all HFPS devices could be operated either under local or full remote control from all sites. Multi-site remote control of Laerdal and METI machines was made possible by proprietary HFPS bridging developed by MedSMART that utilises digitised physiological outputs of one simulator as the controlling element of driving the other unit. Bridging software was loaded into the memory of the local (machine-slaved) control computers at either HFPS location. The machines were then programmed to allow either concerted or independent action, with the operational control seamlessly transferable between the operator stations in Ann Arbor, Alpena, Laval, or L'Aquila. Multi-site control capability allowed random introduction of unpredictable and confounding medical events (e.g., sudden haemorrhages, adverse drug reactions, or malfunctions of patient monitoring systems). Introduction of medical unpredictability proved to be an important tool amplifying the sense of medical realism and urgency 'suspension of disbelief').

8 Future developments and challenges

8.1 Visualisation

The most essential aspect of simulation based distance training is visualisation of the simulating devices. Both image quality and the field of vision must be identical to those at the simulator site. Even if endowed with pan/tilt/zoom capacity, single-view cameras do not allow such views and multiple systems need to be used. In order to ensure maximum flexibility, all cameras must be under remote control from the central control station (Figure 3), and the control devices must allow simultaneous operation of both on-site and remote cameras. Effective, multi-camera control systems are commercially available and their use offers the most practical solution, even if (at times), it may be quite expensive and technologically complex. The most critical aspect of camera operation is the calibration of the individual units' field of view, particularly in the context of multi-site activities when centrally located simulators are operated from a large number of remote learner sites. Under such conditions, the view of the simulator at each remote site must be identical to that displayed at all other sites. In our experience, when only limited image transmission resources are available, limitations of the typical videoconferencing systems allow only 3–4 sites that can be optimally served by a single camera unit. Addition of further sets fragments the available bandwidth and results in a substantial deterioration of image quality at the remote sites. While mounting camera sets in the angle of view-corrected racks provides a simple but rather cumbersome solution, the use of either wavelet compression software such as WINVICOS (Graschew et al., 2002) or integration with comprehensive medical communication systems (Holcomb, 2002) provides a much more optimal and robust approach. It must be remembered, though, that the need to have compression executed at the transmission site limits its use to the more technologically advanced remote sites. The same is true of integration into complex communication systems that will require ready access to telecommunications expertise at the remote site and frequent monitoring of platform performance within the training network. Naturally, in the environments (rare at present) where the available bandwidth is of limited or no concern, substandard bandwidth allocation to each camera set ceases to be an overriding issue.

8.2 Access and remote simulator control

Although many of the most critical problems have been solved, the issue of easy and readily available access to the training centre persists. Access from the periphery to the central facility and vice versa can be obtained either by using point-to-point connectivity, with each remote site having its own IP address and an allocated fast internet connection, dedicated ISDN lines, or through a Web-based portal hosted at the central training facility. The internet-based access without Quality of Service (QOS), although the simplest one, may become unreliable during extended (more than 1 h) continuous transmission due to frequent connection interruptions and slow-downs, or up- and down-load loss of transmission speed that are particularly annoying during long or very long distance operations (e.g., transcontinental or global.) Work in which ISDN-lines, are routinely used is also the most expensive. Access through a Web portal necessitates its creation – a matter of technical complexity that is best accomplished by the technical personnel at the central simulation facility. However, with the portal located at the training facility servers, and a significant part of the operational software necessary for the efficient training (HFPS control/translation software; remote camera control software, training scenario programmes, etc.) accessible through such a portal, multi-site activities become greatly facilitated. The peripheral sites are provided with a simple, intuitively understood simulator interface tool displayed at the remote computer monitor. Control of the simulator is performed either via point-and-click mouse operation or, at a more sophisticated level, by touching appropriate controls on the touch-sensitive screen.

In summary, the central site acts as a broad-concept ASP that, in addition to the simulation-centred software, provides other training elements, e.g., access to more traditional didactic tools, archives of previous simulation-based courses, testing materials, etc. In such a configuration, prior experience indicates that transmission speeds of 128 kilobits are adequate to fulfil all the required tasks without any deterioration in the quality of image/voice/data elements.

Figure 3 Multi-site, multi-simulator control stations. On the left, the operating engineer at the training studio (MedSMART, Ann Arbor, MI) has the view of all distant sites, controls operation of the cameras, voice inputs and sound levels, and is in full control of communication back-up systems, allowing an immediate switch to another line/IP address if the currently active connection fails. Multiple site/multiple simulator technical control is a complex operation that requires highly skilled telecommunication personnel with expertise in TV activities and capable of simultaneously coordinating several sources of input and output correlating these with the training that takes place in the studio. It is the creation of the regional ultra-sophisticated control centers such as the one shown on the right picture (at the College of Health Sciences at Central Michigan University in Mount Pleasant, MI) rather than the arrangements at the remote sites that poses the major difficulty in global-range distributed simulation-based learning.

8.3 *Curriculum*

Development of a suitable training curriculum is among the most essential elements contributing to the success of distributed simulation-based training. Although the approach combines the most effective elements of purely didactic and hands-on training methods, it does not allow the practice of relevant procedures which can be trained only in a direct, physical contact with the simulator. Nonetheless, although provisions for such exposure must be made as a part of the course, distributed training provides solid grounding in the practical principles of overall management of a seriously ill patient. It also hones not only the diagnostic skills, but also prepares for the appropriate procedure selection, and teaches the true relevance of the selected procedures to the particular medical condition. Finally, simulation-based distance training permits viewing of complex procedures as performed by an expert (Von Lubitz et al., 2003 and Figure 4). In the latter context, a stepwise explanation of the correct approach, an analysis of pitfalls in the context of a highly realistic behaviour of the 'simulated' patient in response to inappropriately performed procedures, and the ongoing commentary on the actions that must be taken to ensure its success are among the important elements facilitating subsequent learning of the relevant motor skills (Von Lubitz, 2002; Von Lubitz et al., 2003).

Figure 4 Simulation-based distance training in the performance of complex medical procedures. The upper figure shows the training expert at the central simulation facility (MedSMART, Ann Arbor, MI) instructing a group of junior physicians (left picture) in Italy (L'Aquila) in the execution of fiberoptic intubation. The expert is in real time sound/video contact with his student allowing him not only to demonstrate the procedure itself, but also make a 'running commentary' and either query the trainees or answer their questions. The expert sees the trainees as they are shown in the right picture. The inset view in the white frame (right picture) provides the expert with the scene as seen full scale by his students in Italy, i.e., the process of guiding the fiberscope toward the patient's trachea, and the fiberscope view of the inside of the trachea. The fiberscope view allows students to become familiar with the characteristic landmarks, recognise faulty placement of the device, assist in guiding the tip of the device, and – eventually – perform the entire procedure remotely simply by directing an untrained technician. This type of training is particularly suitable for telemedical consultation and guidance.

The principal goal of the distributed simulation-based training aims at the maintenance of maximum medical realism and a rapid practical preparation of the trainees for the challenges of real-life operations. Hence, the curriculum must incorporate a significantly higher pace and impose significantly higher demands on the active participation of individual trainees than in the didactic or the non-simulated hands-on environments. In the didactic setting, the principal burden of action is placed on the teacher, while the possibility of harm to the patient that may occur in the non-simulated hands-on training demands frequent interventions and guidance by the training expert. In simulated encounters, the burden of action is placed directly on the trainee and allows errors of omission and commission to take place without the risk of adverse or punitive instructor response. The expert's role is not to interrupt and explain while mistakes take place but, once the scenario runs to its end, repeat it and provide thorough debriefing of its entire course. Hence, the curriculum must incorporate simulation of the common patient management errors, demonstrate the influence of human factors and their relation to adverse outcomes, and allow for both individual and team training. Contrary to real life, death of a 'patient' is not a traumatic but potentially a very intense learning experience that need not be avoided. Finally, the need for a focused curriculum cannot be overemphasised. Because each of the potentially involved disciplines has its own training needs, the curriculum must be very specific in its objectives: field management of trauma must concentrate on that topic rather than elements of perisurgical crises that may affect the survival of a traumatised patient. Unless specific goals of simulation-based training are strictly pursued, it can easily degrade into a highly theatrical demonstration of medical emergencies similar to the numerous television shows that vividly depict the bloody nature of field and emergency medicine but are completely useless as training tools.

8.4 Development of Interdisciplinary education standards and models

Emergency medical education would be a valuable core component for all students in health professions including physicians, nurses, physician assistants, physical therapists and others who work with patients and high-risk populations. Distributed simulation-based training is an ideal method of facilitating team-learning across health professions education. It can be delivered to remote clinical training sites or can be provided on-site with collaboration between schools/colleges of health professions (HP). While various HP disciplines have individualised education requirements, a standardised curriculum for simulation-based emergency medical education could be incorporated across professional curricula. Competencies to be mastered are the same for all trainees; therefore, curricular aspects remain the same regardless of previous education/training or experience of the students.

A strong attribute of simulation-based training is the learner-centred design of the curriculum and the delivery method. Outcomes can be quickly assessed allowing trainees to have individualised attention and ample opportunity to master competencies. To insure that trainees in larger classes are uniformly engaged, participatory exercises, such as question/discussion instruments, can be completed by students during the training session for use in later interdisciplinary discussions. This type of exercise lends itself to a variety of educational models such as Case-Based Training, Problem-Based Learning, as well as traditional interdisciplinary discussion models.

In times of local or national disaster, those in the health professions are the first to be sought out for assistance. This makes a strong case for including simulation-based emergency training as a core component in the educational process for all students in health professions. Numbers of healthcare personnel who are competent in the field of pre-hospital emergency care could be dramatically increased without significant cost added to health professions education.

9 Conclusions

The efficacy of simulation-based distance training using the approach described in this paper has been published elsewhere (Treloar et al., 2001; Von Lubitz et al., 2003, 2004). Here, suffice to say that the majority of our remote trainees (89%, N=126) declared 'very high satisfaction with the quality of training and technology,' and stated a very high quality learning experience based on the use of remote access to medical simulation.

From the technical point of view, our experiments show that a successful HFPS network can be created with moderate ease, and that such a network can perform effectively at very large distances (over 7000 km between Laval/L'Aquila and Ann Arbor.) Importantly, while less sophisticated than pure VR-based medical training systems, HFPS networks utilising concepts of Advanced Distributed Learning (ADL) are vastly cheaper to build, operate and maintain compared to VR-based federations. Hence, they are also much more readily available to the majority of the medical personnel who work in the environment insufficient to support the expense and technical knowledge required by the advanced VR technology. In this context, it needs to be mentioned that the simulator-connecting software bridge that allowed simultaneous use of simulators produced by two different companies is not the optimal solution. A far more flexible platform would be based on a Web portal allowing greater ease of operations and – most significantly – essentially unlimited scaleability. It is the latter aspect that is probably the most critical in the context of large, global range simulator networks. While ideal, the latter solution also requires that machine-generated data are standardised using broadly agreed rules (e.g. HL7). Surely, increasing the use of HFPS devices and the need to combine them into collaborative 'patient suites' will provide enough driving force to implement such standardisation.

In similarity to VR-based medical training devices (Agazio, et al., 2002; Gallagher and Satava, 2002; Proctor and Creech, 2001), both individual HFPS units and ADL networks utilising them offer a sufficiently high level of versatility and the associated 'suspension of disbelief' to create highly efficient training tools (Von Lubitz, 2002; Von Lubitz et al., 2001, 2003, 2004). Both VR and HFPS approaches to medical simulation have their advantages and disadvantages. Combining both may lead to a significant enhancement of both the efficacy and intensity of training (Von Lubitz, 2002; Von Lubitz et al., 2000a,b) and convert the present, largely explorative arena of medical simulation into an indispensable tool that simulation provides today in practically all aspects of aviation and maritime education and training.

In conclusion, we have demonstrated that, from the technology point of view, a multi-simulator environment in which distance is the most limiting factor, can be used a powerful training tool at both national and international scale. We have also shown that the tool is an effective one (Treloar et al., 2001; Von Lubitz et al., 2003, 2004). However, demonstration of usefulness does not obviate the need for further intensive, metrics-based research on the medical uses of simulation. The work of Gallagher and his colleagues (Gallagher and Satava, 2002; Seymour et al., 2002) is the pointer in the direction that future studies must take in order to prove convincingly the value of medical simulation (Bloom et al., 2003; Holcomb, 2002; Pittini et al., 2002). Other subjects, e.g., evaluation of human factors in medicine, testing of telemedical concepts and models, large scale simulation of healthcare operations (e.g., hospital simulation or healthcare management simulation starting at the individual patient level and ending on national-level administration of the related expenditures see Von Lubitz et al., 2000a) come to mind as well. Similarly to defence and aviation, in medicine simulation also appears to open completely new and unprecedented possibilities (Myjak and Rosen, 2001; Von Lubitz, 2002)

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References

Agazio, J.B., Pavlides, C.C., Lasome, C.E., Flaherty, N.J. and Torance, R.J. (2002) 'Evaluation of a virtual reality simulatorin sustainment training', *Mil. Med.*, 167, pp.893–897.

Agazio, J.B., Pavlides, C.C., Lasome, C.E., Flaherty, N.J. and Torrance, R.J. (2002) 'Evaluation of a virtual reality simulator in sustainment training', *Mil. Med.*, 167, pp.893–897.

Allen, M., Sargeant, J., McDougall E. and O'Brien, B. (2002) 'Evaluation of videoconferencing grand rounds', *J Telemed Telecare*, 8, pp.210–216.

Allen, M., Sargeant, J., McDougall, E. and Proctor-Simms, M. (2002) 'Videoconferencing for continuing medical education: from pilot project to sustained programme', *J Telemed Telecare*, 8, pp.131–137.

Bair, A.E., Filbin, M.R., Kulkarni, R.G. and Walls, R.M. (2002) 'The failed intubation attempt in the emergency department: analysis of prevalence, rescue techniques, and personnel', *J Emerg. Med.*, 23, pp.131–140.

Baker, D.J. (1999) 'Management of respiratory failure in toxic disasters', *Resuscitation*, 42, pp.125–131.

Billingham, K., Howe, A. and Walters, C. (2002) 'In our own image – a multidisciplinary qualitative analysis of medical education', *J Interprof Care*, 16, pp.379–389.

Block, E.F., Lottenberg, L., Flint, L., Jakobsen, J. and Liebnitzky, D. (2002) 'Use of human patient simulator for the advanced trauma life support course', *Am. Surg.*, 68, pp.648–651.

Bloom, M.B., Rawn, C.L., Saltzberg, A.D. and Krummel, T.M. (2003) 'Virtual reality applied to procedural training', *Ann. Surg.*, 237, pp.442–448.

Bond, W.F. and Spillane, L. (2002) 'The use of simulation for emergency medicine resident assessment', *Acad. Emerg. Med.*, 9, pp.1295–1299.

Booth, B. and Lawrance, R. (2001) 'Quality assurance and continuing education needs of rural and remote general practitioners: how are they changing?', *Aust J Rural Health*, 9, pp.256–274.

Bradley, J.S., Billows, G.L., Olinger, M.L., Boha, S.P., Cordell, W.H. and Nelson, D.R. (1998) 'Prehospital oral endotracheal intubation by rural basic emergency medical technicians', *Ann. Emerg. Med.*, 32, pp.26–32.

Brannick, M.T., Prince, A., Prince, C. and Salas, E. (1995) 'The measurement of team process', *Hum. Factors*, 37, pp.641–651.

Brocato, C.E. and Miller, G.T. (2002) 'The next agent of terror? Understanding smallpox & its implications for prehospital crews', *J Emerg. Med. Serv. JEMS*, 27, pp.52–55.

Buckingham, C.D. and Adams, A. (2000) 'Classifying clinical decision making: a unifying approach', *J Adv. Nurs.*, 32, pp.981–990.

Burd, A., Cheung, K.W., Ho, W.S., Wong, T.W., Ying, S.Y. and Cheng, P.H. (2002) 'Before the paradigmshift: concepts and communication between doctors and nurses in a burns team', *Burns*, 28, pp.691–695.

Byrne, A.J. and Jones, J.G. (1997) 'The expanding role of simulators in risk management', *Br. J Anaesth.*, 79, pp.411.

Casebeer, L., Allison, J. and Spettell, C.M. (2002) 'Designing tailored web-based instruction to improve practicing physicians' chlamydial screening rates', *Acad. Med.*, 77, pp.929.

Caudell, T.P., Summers, KL., Holten, J. 4th., Hakamata, T., Mowafi, M., Jacobs, J., Lozanoff, B.K., Lozanoff, S., Wilks, D., Keep, M.F., Saiki, S. and Alverson, D., (2003) 'Virtual patient simulator for distributed collaborative medical education', *Anat. Res.*, 270B, pp.23–29.

Cayten, C.G., Herrmann, N., Cole, L.W. and Walsh, S. (1978) 'Assessing the validity pof EMS data', *JACEP*, 7, pp.390–396.

Chiara, O., Scott, JD., Cimbanassi, S., Marini, A., Zoia, R., Rodriguez, A. and Scalea, T. (2002) 'Trauma deaths in an Italian urban area: an audit of pre-hospital and in-hospital trauma care', *Injury*, 33, pp.553–562.

Colliver, J.A. (2002) 'Educational theory and medical education practice: a cautionary note for medical school faculty', *Acad. Med.*, 77, pp.1217–1220.

Cone, K.J. and Murray R. (2002) 'Characteristics, insights, decision making, and preparation of ED triage nurses', *J Emerg. Nurs.*, 28, pp.401–406.

Connor, M., Ponte, P.R. and Conway, J. (2002) 'Multidisciplinary approaches to reducing error and risk in a patient care setting', *Crit, Care Nurs. Clin. North Am.*, 14, pp.359–367.

Coontz, D.A. and Gratton, M. (2002) 'Endotracheal rules of engagement. How to reduce the incidence of unrecognized esophageal intubations', *J Emerg. Med. Serv. JEMS*, 27, pp.44–50, 52–54, 56–59.

Cooper, J.B., Newbower, R.S., Long, C.D. and McPeek, B. (2002) 'Preventable anesthesia mishaps: a study of human factors', *Qual. Saf. Healthcare*, 11, pp.277–282.

Cosman, P.H., Cregan, P.C., Martin, C.J. and Cartmill, J.A. (2002) 'Virtual reality simulators: current status in acquisition and assessment of surgical skills', *ANZ J Surg.*, 72, pp.30–34.

Cowley, R.A., Myers, R.A. and Gretes, A.J. (1984) 'EMS response to mass casualties', *Emerg. Med. Clin. North Am.*, 2, pp.687–692.

Cunha, B.A. (2002) 'Anthrax, tularemia, plague, ebola or smallpox as agents of bioterrorism: recognition in the emergency room', *Clin. Microbiol. Infect.*, 8, pp.489–503.

Cupera, J., Mannova, J., Rihova, H., Brychta, P. and Cundrle, I. (2002) 'Quality of prehospital management of patients with burn injuries – a retrospective study', *Acta. Chir. Plast.*, 44, pp.59–62.

Darling, R.G., Huebner, K.D., Noah, D.L. and Waeckerle, J.F. (2002) 'The history and threat of biological warfare and terrorism', *Emerg. Med. Clin. North Am.*, 20, pp.255–271.

Davis, P. and McCraken, P. (2002) 'Restructuring rural continuing medical education through videoconferencing', *J Telemed Telecare*, 8, pp.108–109.

Davis, P. and McCraken, P. (2002) 'Restructuring rural continuing medical education through videoconferencing', *J Telemed Telecare*, 8, pp.108–109.

De Leo, G., Krishna, S., Balas, E.A., Maglaveras, N., Boren, S.A., Beltrame, F. and Fato, M. (2002) *WEB-WAP Based Telecare, Proc. AMIA Symp.*, pp.202–204.

De Lorenzo, R.A. (1993) 'Prehospital misidentification of tachydysrhythmias: a report of five cases', *J. Emerg. Med.*, 11, pp.431–436.

DeAnda, A. and Gaba, DM. (1990) 'Unplanned incidents during comprehensive anesthesia simulation', *Anesth. Analg.*, 71, pp.77–82.

Delaney, G., Khadra, M.H., Lim, S.E., Sar, L., Sturmberg, J.P. and Yang, S.C. (2002) 'Challenges to rural medical education: a student perspective', *Aust. J Rural Health*, 10, pp.168–172.

Deodhar, J. (2002) 'Telemedicine by email – experience in neonatal care at a primary care facility in rural India', *J Telemed Telecare*, 8, pp.20–21.

Devitt, J.H., Kurrek, M.M., Cohen, M.M. and Cleave-Hogg, D. (2001) 'The validity of performance assessments using simulation', *Anesthesiology*, 95, pp.36–42.

Dick, M.L., Johnston, C. and Schluter, P. (2002) 'Managing emergencies in general practice. How can we do even better?', *Aust. Fam. Physician*, 31, pp.789–790.

Dick, M.L., Schluter, P., Johnston, C. and Coulthard, M. (2002) 'GP's perceived competence and comfort in managing medical emergencies in southeast Queensland', *Aust. Fam. Physician*, 31, pp.870–875.

Donini-Lenhoff, F.G. and Hedrick, HL. (2000) 'Growth of specialization in graduate medical education' *JAMA*, 284, pp.1284–1289.

Dornan, T., Carroll, C. and Parboosingh, J. (2002) 'An electronic learning portfolio for elective continuing professional development', *Med. Educ.*, 36, pp.767–769.

Doyle, C.J. (1990) 'Mass casualty incident. Integration with prehospital care', *Emerg. Med. Clin. North Am.*, 8, pp.163–175.

Eberle, B., Dick, W.F., Schneider, T., Wisser, G., Doetsch, S. and Tzanova, I. (1996) 'Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse', *Resuscitation*, 33, pp.107–116.

Elkin, P.L. and Gorman, P.N. (2002) 'Continuing medical education and patient safety: an agenda for lifelong learning', *J Am. Med. Inform. Assoc.*, 9, pp.S128–S132.

el-Tobgy, E. and Rupp, T. (2002) 'Anaphylaxis. Vicious chain reaction', *J Emerg. Med. Serv. JEMS*, 27, pp.84–88, 90–93.

Fahlgren, T.L. and Drenkard, K.N. (2002) 'Healthcare system disaster preparedness, part 2: nursing executive role in leadership', *J Nurs. Adm.*, 32, pp.531–537.

Fay, V., Feldt, K.S., Greenberg, S.A., Vezina, M., Flaherty, E., Ryan, M. and Fulmer, T. (2001) 'Providing optimal hands-on experience. A guide for clinical preceptors', *Adv. Nurse Pract.*, 9, pp.71–74, 110.

Fellander-Tsai, L., Stahre, C., Anderberg, B., Barle, H., Bringman, S., Kjellin, A., Ramel, S., Strinnlund, B., Carlson, C. and Wredmark, T. (2001) 'Simulator training in medicine and healthcare: a new pedagogic model for good patient safety', *Laekertidn.*, 98, pp.3772–3776.

Fieschi, M., Soula, G., Giorgi, R., Gouvernet, J., Fieschi, D., Botti, G., Volot, F and Berland, V (2002) 'Experimenting with new paradigms for medical education and emergence of distance learning degree using the internet: teaching evidence-based medicine', *Med. Inform. Internet Med*. 27, 1-11

Fletcher, J.L. (1995) 'AANA journal course: update for nurse anesthetists – anethesia simulation: a tool for learning and research', *AANA J*, 63, pp.61–67.

Forrest, F.C., Taylor, M.A., Postlethwaite, K. and Aspinall, R. (2002) 'Use if high fidelity simulator to develop testing of the technical performance of novice anaesthetists', *Br. J. Anaesth.*, 88, pp.338–344.

Forti, E.M., Martin, KE., Jones, R.L. and Herman, J.M. (1996) 'An assessment of practice support and continuing medical education needs of rural Pennsylvania family physicians', *J Rural Health*, 12, pp.432–437.

Friedrich, M.J. (2002) 'Practice makes perfect: risk-free medical training with patient simulators', *JAMA*, 288, pp.2811–2812.

Fritsche, L., Greenhalgh, T., Falck-Ytter, Y., Neumayer, H.H. and Kunz, R. (2002) 'Do short courses in evidence based medicine improve knowledge and skills? Validation of Berlin questionnaire and before and after study of courses in evidence based medicine', *BMJ*, 325, pp.1338–1341.

Gaba, D.M. and DeAnda, A. (1988) 'A comprehensive anesthesia environment: re-creating the operating room for research and training', *Anesthesiology*, 69, pp.387–394.

Gage, H., Kenward, G., Hodgetts, T.J., Castle, N., Ineson, N. and Shaikh, L. (2002) 'Health system costs of in-hospital cardiac arrest', *Resuscitation*, 54, pp.139–146.

Gallagher, A.G. and Satava, RM. (2002) 'Virtual reality as a metric for the assessment of laparoscopic skills: Learning curves and reliability measures', *Surg.Endosc.*, 16, pp.1746–1752.

Garden, A., Robinson, B., Weller, J., Wilson, L. and Crone, D. (2002) 'Education to address medical error-a role for high fidelity patient simulation', *N Z Med. J*, 115, pp.133–134.

George, G., Ramsay, K., Rochester, M., Seah, R., Spencer, H., Vijayasankar, D. and Vasicuro L. (2002) 'Facilities for chemical decontamination in accident and emergency departments in the UK', *Emerg. Med. J.*, 19, pp.453–457.

Girdler, N.M. (2001) 'Competency in sedation', *Br. Dent. J*, 191, pp.119.

Girgis, A., Sanson-Fisher, R.W. and Walsh, RA. (2001) 'Preventive and other interactional skills of general practitioners, surgeons, and physicians: perceived competence and endorsement of postgraduate training', *Prev. Med.*, 32, pp.73–81.

Gold, J.P., Verrier, E.A., Olinger, G.N. and Orringer, M.B. (2002) 'Development of a CD-ROM internet hybrid: a new thoracic surgery curriculum', *Ann. Thorac. Surg.*, 74, pp.1741–1746.

Gonzalez, Y.M. and Mohl, N.D. (2002) 'Care of patients with temporomandibular disorders: an educational challenge', *J Orofac. Pain*, 16, pp.200–206.

Gordon, J.A. and Pawlowski, J. (2002) 'Education on-demand: the development of a simulator-based medical education service', *Acad. Med.*, 77, pp.751–721.

Gordon, J.A., Wilkerson, W.M., Shaffer, DW. and Armstrong, EG. (2001) 'Practicing medicine without risk: students' and educators' responses to high-fidelity patient simulation, *Acad. Med.*, 76, pp.469–472.

Graber, M., Gordon, R. and Franklin, N. (2002) 'Reducing diagnostic errors in medicine: what's the goal?', *Acad. Med.*, 77, pp.981–992.

Graschew, G., Roelofs, T.A., Rakowsky, S. and Schlag, PM. (2002) 'Intereactive telemedical applications in OP 2000 via satellite', *Biomed. Tech.* (Berl), 47, pp.330–333.

Greenberg, R., Loyd, G. and Wesley, G. (2002) 'Integrated simulation experiences to enhance clinical education', *Med. Educ.*, 36, pp.1109–1110.

Greengold, N.L. (2002) 'A web-based program for implementing evidence-based patient safety recommendations', *Jt. Comm. Qual. Improv.*, 28, pp.340–348.

Guay, A.H. (2002) 'Dentistry's response to bioterrorism: a report of consensus workshop', *J Am. Dent. Assoc.*, 133, pp.1181–1187.

Gulesen, O. (2001) 'Specialization of doctors, general practice and the training system', *Can. Sociol. Demogr. Med.*, 41, pp.386–396.

Hall, W.L. and Nowels, D. (2000) 'Colorado family practice graduates' preparation for an practice of emergency medicine', *J Am. Board Fam. Pract.*, 13, pp.246–250.

Hammond, J., Bermann, M., Chen, B. and Kushins, L. (2002) 'Incorporation of a computerized human patient simulator in a critical care training: a preliminary report', *J. Trauma*, 53, pp.1064–1067.

Hans, K. (2002) 'Global standards in medical education for better healthcare', *Med Educ.*, 36, pp.1116.

Haponik, E.F., Russell, G.B., Beamis, J.F. Jr., Britt, E.J., Kvale, P., Mathur, P. and Mehta, A. (2000) 'Bronchoscopy training: current fellows' experiences and some concerns for the future', *Chest.*, 118, pp.625–630.

Harter, P., Krummel, T. and Reznek, M. (2002) 'Virtual reality and simulation: training the future emergency physician', *Acad. Emerg. Med.*, 9, pp.78–87.

Haythornthwaite, S. (2002) 'Videoconferencing training for those working with at-risk young people in rural areas of Western Austrailia', *J Telemed Telecare*, 8, pp.29–33.

Hazard, R.G. (1994) 'The multidisciplinary approach to occupational low back pain and disability', *J Am. Acad. Orthop. Surg.*, 2, pp.157–163.

Herlitz, J., Hansson, E., Ringvall, E., Starke, M., Karlson, B.W. and Waagstein, L. (2002) 'Predicting a life-threatening disease and death among ambulance-transported patients with chest pain or other symptoms raising suspicion of an acute coronary syndrome', *Am. J Emerg. Med.*, 20, pp.588–594.

Hicks, G.D. (2001) 'An appeal for more 'hands-on' surgical training and experience', *Plast. Reconstr. Surg.*, 107, pp.1612–1613.

Hodgetts, T.J., Kenward, G., Vlackonikolis, I., Payne, S., Castle, N., Crouch, R., Ineson, N. and Shaikh, L. (2002) 'Incidence, location and reasons for avoidable in-hospital cardiac arrest in a district general hospital', *Resuscitation*, 54, pp.115–123.

Holcomb, G. (2002) 'Coherent medical informatics'. Available from: http://www.som.tulane.edu/oit/documents/CMI.PDF.

Holcomb, J.B., Dumire, R.D., Crommett, J.W., Stamateris, C.E., Fagert, M.A., Cleveland, J.A., Dorlac, G.R., Dorlac, W.C., Bonar, J.P., Hira, K., Aoki, N. and Mattox, K.L. (2002) 'Evaluation of trauma team performance using an advanced human patient simulator for resuscitation training', *J. Trauma*, 52, pp.1078–1085.

Holliman, C.J., Wuerz, R.C. and Meador, S.A. (1992) 'Medical command errors in an urban advanced life support system', *Ann. Emerg. Med.*, 21, pp.347–350.

Hotchkiss, M.A. and Mendoza, S.N. (2001) 'Update for nurse anesthetists. Part 6. Full-body patient simulation technology: gaining experience using a malignant hyperthermia model', *AANA J*, 69, pp.59–65.

Hoyal, F.M. (1999) 'Swallowing the medicine: determining the present and desired modes for delivery of continuing medical education to rural doctors', *Aust. J Rural Health*, 7, pp.212–215.

http://www.flightofthephoenix.org/link_trainer.htm.

Hubble, M.W., Paschal, K.R. and Sanders, T.A. (2000) 'Medication calculation skills of practicing paremedics', *Prehosp. Emerg. Care*, 4, pp.253–260.

Isenberg, S.B., Gordon, M.S., Safford, R.E. and Hart, I.R. (2001) 'Simulation and new earning technologies', *Med.Tech.*, 23, pp.16–23.

Issenberg, S.B., McGaghie, W.C., Hart, IR., Mayer, J.W., Felner, J.M., Petrusa, E.R., Waugh, R.A., Brown, DD., Safford, R.R., Gessner, I.H., Gordon, D.L., Ewy and G.A. (1999) 'Simulation technology for health professional skills training and assessment', *JAMA*, 282, pp.861–866.

Jeanguiot, N.P. (2000) 'Learning by mistake. The status of error in the initial education of nurses', *Rech. Soins. Infirm.*, pp.36–78.

Johnston, C.L., Coulthard, M.G., Schluter, P.J. and Dick, M.L. (2001) 'Medical emergencies in general practice in south-east Queensland: prevalence and practice preparedness', *Med. J Aust.*, 175, pp.99–103.

Kanter, R.K., Fordyce, W.E. and Tompikns, J.M. (1990) 'Evaluation of resuscitation proficiency in simulation: the impact of simultaneous cognitive task', *Pediatr. Emerg. Care*, 6, pp.260–262.

Kanz, K.G., Sturm, J.A. and Mutschler, W. (2002) 'Algorithm for prehospital blunt trauma management', *Unfallchirurg.*, 105, pp.1007–1014.

Karnath, B., Frye, A.W. and Holden, M.D. (2002) 'Incorporating simulators in a standardized patient exam', *Acad. Med.*, 77, pp.754–755.

Kegley, J.A. (2002) 'Genetics decision-making: a template for problems with informed consent', *Med. Law.*, 21, pp.459–471.

Kelly., L. (1998) 'Surgical skills for family physicians. Do family physicians make the cut?', *Can. Fam. Physician*, 44, pp.476–477.

King, P.H., Pierce, D., Higgins, M., Beattie, C. and Waltman, L.B. (2000) 'A proposed method for the measurement of anaesthetist care variability', *J. Clin. Monit. Comput.*, 16, pp.121–125.

Knowles, W.B. (1967) 'Aerospace simulation and human performance research', *Hum. Factors*, 9, pp.149–159.

Koplan, J. (2001) 'CDC's strategic plan for bioterrorism preparedness and response', *Public Health Rep.*, 116, Suppl. 2, pp.9–16.

Krebs, W.K., McCarley, J.S. and Bryant, E.V. (1999) 'Effects of mission rehearsal simulation on air-to-ground target acquisition', *Hum. Factors*, 41, pp.553–558.

Lalich, R.A. (2002) 'The role of state government, local government, and nongovernmental organizations in medical innovative readiness training', *Mil. Med.*, 167, pp.367–369.

Lamminen, H., Niiranen, S., Niemi, K., Mattila, H., Kalli, S. (2002) 'Health related services on the Interent', *Med. Inform. Internet Med.*, 27, pp.13–20.

Lancaster, T., Hart, R. and Gardner, S. (2002) 'Literature and medicine: evaluating a special study module using the nominal group technique', *Med. Educ.*, 36, pp.1071–1076.

Lary, M.J., Pletcher, T. and von Lubitz., D.K.J.E. (2003) 'Distance-based mass medical readiness training for prehospital providers', *SSGRR Internet Conference*, L'Aquila, Italy. Available from: http://www.ssgrr.it/en/ssgrr2003s/panel.htm.

Lefrancois, D.P. and Dufour, D.G. (2002) 'Use of the esophageal tracheal combitube by basic emergency medical technicians', *Resuscitation*, 52, pp.77–83.

Leitch, R.A., Magee, H. and Moses, G.R. (2002) 'Simulation and the future of military medicine', *Mil. Med.*, 167, pp.350–354.

Letterie, G.S. (2002) 'How virtual reality may enhance training in obstetrics and gynecology', *AM J Obstet. Gynecol.*, 187, pp.S37–S40.

Levi, L., Michaelson, M., Admi, H., Bregman, D. and Bar-Nahor, R. (2002) 'National strategy for mass casualty situations and its effects on the hospital', *Prehospital Disaster Med.*, 17, No. 1, pp.12–16.

Liberman, M., Lavoie, A., Mulder, D. and Sampalis, J. (1999) 'Cardiopulmonary resuscitation: errors made by pre-hospital emergency medical personnel', *Resuscitation*, 42, pp.47–55.

Linder, G., Murphy, P. and Streger, M.R. (2001) 'You did what? Clinical errors in EMS', *Emerg. Med. Serv.*, 30, pp.69–71.

Lingard, L., Reznick, R., DeVito, I. and Espin, S. (2002) 'Forming professional identities on the healthcare team: discursive constructions of the 'other' in the operating room', *Med. Educ.*, 36, pp.728–734.

Linn, S., Knoller, N., Giligan, C.G. and Dreifus, U. (1997) 'The sky is a limit: errors in prehospital diagnosis by flight physicians', *Am. J Emerg. Med.*, 15, pp.316–320.

Loutfi, A., McLean, A.P. and Pickering, J. (1995) 'Training general practitioners in surgical and obstetrical emergencies in Ethiopia', *Trop. Doct.*, 25, No. 1, pp.22–26.

Luiz, T., Hees, K. and Ellinger, K. (1997) 'Prehospital management of emergency patients after previous treatment by general practitioners – a prospective study', *Anasthesiol Intensivmed Notfallmed Schmerzther*, 32, pp.726–733.

Mackenzie, C.F., Jefferies, N.J., Hunter, W.A., Nernhard, W.N. and Xiao, Y. (1996) 'Comparison of self-reporting of deficiencies in airway management with video analysis of actual performance. LOTAS group. Level one Trauma Anesthesia Simulation', *Hum. Factors*, 38, pp.623–635.

Mandavia, D.P., Argona, J., Chan, L., Chan, D., Henderson, S.O. (2000) 'Ultrasound training for emergency physicians- a prospective study', *Acad. Emerg. Med.*, 7, pp.1008–1014.

Mann, T. and Colven, R. (2002) 'A picture is worth more than a thousand words: enhancement of a pre-exam telephone consultation in dermatology with digital images', *Acad. Med.*, 77, pp.742–743.

Marshall, J.N., Stewart, M. and Ostbye, T. (2001) 'Small-group CME using e-mail discussions. Can it work?', *Can. Fam. Physician*, 47, pp.557–563.

Marshall, R.I., Smith, J.S., Gorman, P.J., Krummel, T.M., Haluck, R.S. and Conney, R.N. (2001) 'Use of human patient simulator in the development of resident trauma management skills', *Vol. J. Trauma*, 51, pp.17–21.

Mil'kov, B.O., Shamrei, G.P., Stashchuk, V.F., Deibuk, G.D. and Kulachek, F.G. (1988) 'Training of the general physician in the problems of emergency surgical care', *Sov. Zdravookhr*, 7, pp.46–48.

Modell, J.H., Cantwell, S., Hardcastle, J., Robertson, S. and Pablo, L. (2002) 'Using human patient simulator to educate students of veterinary medicine', *J.Vet.Med. Educ.*, 29, pp.111–116.

Morgan, P.J. and Cleave-Hogg, D. (2002) 'Comparison between medical students' experience and competence', *Med. Educ.*, 36, pp.534–539.

Morgan, P.J. and Cleave-Hogg, D.M. (2001) 'Cost and resource implications of undergraduate simulator-based education', *Can. J. Anaesth.*, 48, pp.827–828.

Moseley, T.H., Cantrell, M.J. and Deloney, L.A. (2002) 'Clinical skills center attending: an innovative senior medical school elective', *Acad. Med.*, 77, pp.1176.

Murphy, A.W., Bury, G. and Dowling, E.J. (1995) 'Teaching immediate cardiac care to general practitioners: a faculty-based approach', *Med. Educ.*, 29, pp.154–158.

Murray, D., Boulet, J., Ziv, A., Woodhouse, J., Kras, J. and McAllister, J. (2002) 'An acute care skills evaluation for graduating medical students: a pilot study using clinical simulation', *Med. Educ.*, 36, pp.833–841.

Murray, W.B. and Foster, P.A. (2000) 'Crisis resource management among strangers: principles of organizing a multidisciplinary group for crisis resource management', *J. Clin. Anest.*, 12, pp.633–638.

Myjak, M.D. and Rosen, J. (2001) 'MEDNET: a medical simulation network grand challenge', *Stud. Health. Technol. Inform.*, 81, pp.341–347.

Nagoshi, M.H. (2001) 'Role of standardized patients in medical education', *Hawaii Med. J*, 60, pp.323–324.

O'Donnell, J., Fletcher, J., Dixon, B. and Palmer, L. (1998) 'Planning and implementing an anaesthesia crisis resource management course for student nurse anaesthetists', *CRNA*, 9, pp.50–58.

Orient, J.M., Lindsay, D. and Whitney, P.J. (1982) 'Educating primary physicians in emergency surgical procedures', *South Med. J*, 75, pp.852–854.

Pastuszak, J. and Rodowicz, M.O. (2002) 'Internal e-mail: an avenue of educational opportunity', *J Contin. Educ. Nurs.*, 33, pp.164–177.

Patterson, P.E. (2002) 'Development of a learning module using a virtual environment to demonstrate EMG and telerobotic control principles', *Biomed. Sci. Instrum.*, 38, pp.313–316.

Peacock, J.B., Blackwell, V.H. and Wainscott, M. (1985) 'Medical reliability of advanced prehospital cardiac life support', *Ann. Emerg. Med.*, 14, pp.407–409.

Peleg, K., Reuveni, H. and Stein, M. (2002) 'Earthquake disasters-lessons to be learned', *Isr. Med. Assoc. J*, 4, pp.361–365.

Pittini, R., Oepkes, D., Macrury, K., Reznick, R., Beyene, J. and Windrim, R. (2002) 'Teaching invasive perinatal assessment of a high fidelity simulator-based curriculum', *Ultrasound Obstet. Gynecol.*, 19, pp.478–483.

Pittini, R., Oepkes, D., Macrury, K., Reznick, R., Beyene, R. and Windrim, R. (2002) 'Teaching invasive perinatal procedures: assessment of a high fidelity simulator- based curriculum', *Ultrasound Obstet. Gynecol.*, 19, pp.478–483.

Porter, R. (1997) *The Greatest Benefit to Mankind: A Medical History of Humanity*, Norton & Co., pp.3–831.

Poyner, A., Wood, A. and Herzberg, J. (2002) 'Distance learning project-information skills training: supporting flexible trainees in psychiatry', *Health Info. Libr. J*, 19, pp.84–89.

Proctor, M.D., Creech, G.S. (2001) 'Object-oriented modeling of patients in a medical federation', *IEEE Trans. Inf. Technol. Biomed.*, 5, pp.244–247.

Rall, M., Schaedle, B., Zieger, J., Naef, W. and Weinlich, M. (2002) 'Innovative training for enhancing patient safety. Safety culture and integrated concepts', *Unfallchirurg*, 105, pp.1033–1042.

Reid, S.J., Chabikuli, N., Jaques, P.H. and Fehrsen, G.S. (1999) 'The procedural skills of rural hospital doctors', *S Afr. Med. J*, 89, pp.769–774.

Ricard, G.L. (1995) 'Acquisition of control skill with delayed and compensated displays', *Hum. Factors*, 37, pp.652–658.

Robinson, G. (2002) 'Do general practitioners' risk-taking propensities and learning styles influence their continuing medical education preferences?', *Med. Tech.*, 24, pp.71–78.

Ronco, R., King, W., Donley, DK. and Tilden, SJ. (1995) 'Outcome and cost at a children's hospital following resuscitation for out-of-hospital cardiopulmonary arrest', *Arch. Pediatr. Adolesc. Med.*, 149, pp.210–214.

Rosemurgy, A.S., Norris, P.A., Olson, S.M., Hurst, J.M. and Albrink, M.H. (1993) 'Prehospital traumatic cardiac arrest: the cost of futility', *J Trauma*, 35, pp.473–474.

Rosenblatt, M.A., Abrams, K.J., NY State Soc. Annesthesiol. Inc., Comm. Contd. Med. Educ. and Remed., Remed. Sub-Comm (2002) 'The use of a human patient simulator in the evaluation and development of a remedial prescription for an anaesthesiologist with lapsed medical skills', *Anesth. Analg.*, 94, pp.149–153.

Rourke, J.T. (1994) 'Rural advanced life support update course', *J Emerg. Med.*, 12, pp.107–111.

Rourke, J.T. and Rourke, L.L. (1995) 'Rural family medicine training in Canada', *Can. Fam. Physician*, 41, pp.993–1000.

Rubinshtein, R., Robenshtok, E., Eisenkraft, A., Vidan, A. and Hourvitz, A. (2002) 'Training Israeli medical personnel to treat casualties of nuclear, biologic, and chemical warefare', *Isr. Med. Assoc.*, 4, pp.545–548.

Ruppert, M., Reith, M.W., Widmann, J.H., Lackner, C.K., Kerkmann, R., Schweiberer, L. and Peters, K. (1999) 'Checking for breathing: evaluation of the diagnostic capability of emergency medical services personnel, physicians, medical students, and medical laypersons', *Ann. Emerg. Med.*, 34, pp.720–729.

Sanson-Fisher, R.W., Rolfe, I.E., Jones, P., Ringland, C. and Agrez, M. (2002) 'Trialling a new way to learn clinical skills: systematic clinical appraisal and learning', *Med. Educ.*, 36, pp.1028–1034.

Schaefer, J.J. 3rd and Grenvik, A. (2001) 'Simulation-based training at the University of Pittsburgh', *Ann. Acad. Med. Singapore*, 30, pp.274–280.

Scheen, A.J., Rorive, M., Letiexhe, M., Devoitille, L. and Jandrain, B. (2001) 'Multidisciplinary management of the obese patient: example from the Obesity Center at the University of Liege', *Rev. Med. Liege*, 56, pp.474–479.

Schriefer, J., Engelhard, J., DiCesare, L., Miller, M. and Schriefer, J. (2000) 'Merging clinical pathway programs as part of overall health systems mergers: a ten-step guide. Spectrum Health', *Jt. Comm. J Qual. Improv.*, 26, pp.29–38.

Schroeder, S.A. (2002) 'Primary care at a crossroads', *Acad. Med.*, 77, pp.767–773.

Schwid, H.A., Rooke, G.A., Carline, J., Steadman, R.H., Murray, W.B., Olympio, M., Tarver, S., Steckner, K. and Wetstone, S. 'The Anesthesia Simulator Research Consortium, 2002. Evaluation of anesthesia residents using mannequin-based simulation: a multiinstitutional study', *Anethesiology*, 97, pp.1434–1444.

Seidel, J.S., Henderson, D.P., Ward, P., Wayland, B.W. and Ness, B. (1991) 'Pediatric prehospital care in urban and rural areas', *Pediatrics*, 88, pp.681–690.

Seidel, J.S. (1986) 'Emergency medical services and the pediatric patient: are the needs being met? II. Training and equipping emergency medical services providers for pediatric emergencies', *Pediatrics*, 78, pp.808–812.

Seymour, N.E., Gallagher, A.G., Roman, S.A., O'Brien, M.K., Bansal, V.K., Anderson, D.K. and Satava, R.M. (2002) 'Virtual reality training improves operating room performance: results of a randomized, doubleblinded study', *Ann. Surg.*, 236, pp.463–464.

Shapiro, M. and Morchi, R. (2002) 'High-fidelity medical simulation and teamwork training to enhance medical student performance in cardiac resuscitation', *Acad. Emerg. Med.*, 9, pp.1055–1056.

Sherwood, G., Thomas, E., Bennett, D.S. and Lewis, P. (2002) 'A teamwork model to promote patient safety in critical care', *Crit. Care Nurs. Clin. North Am.*, 14, pp.333–340.

Simon, H.K., Steele, D.W., Lewander, W.J. and Linakis, J.G. (1994) 'Are pediatric emergency medicine training programs meeting their goals and objectives? A self-assesment of individuals completing fellowship training in 1993', *Pediatr. Emerg. Care*, 10, pp.208–212.

Simon, H.K. and Sullivan, F. (1996) 'Confidence in performance of pediatric emergency procedures by community emergency practitioners', *Pediatr. Emerg. Care*, 12, pp.336–340.

Small, S.D., Wuertz, R.C., Simon, R., Shapiro, N., Conn, A. and Setnik, G. (1999) 'Demonstration of high fidelity simulation team training for emergency medicine', *Acad. Emerg. Med.*, 6, pp.213–223.

Snyder, W. and Smit, S. (1998) 'Evaluating the evaluators: interrater reliability on EMT licensing examination', *Prehosp. Emerg. Care*, 2, pp.37–46.

Sohier, N., Frejacques, L. and Gagnayre, R. (1999) 'Design and implementation of a training programme for general practitioners in emergency surgery and obstetrics in precarious situations in Ethiopia', *Ann. R Coll. Surg. Engl.*, 81, pp.367–375.

Somers, G.T, Maxfield, N. and Drinkwater, E.J. (1999) 'General practitioner preparedness to respond to a medical disaster. Part I: Skills and Equipment', *Aust. Fam. Physician*, 28, pp.S3–S9.

Spence, A.A. (1997) 'The expanding role of simulators in risk management', *Br. J Anaesth.*, 78, pp.633–634.

Su, E., Schmidt, T.A., Mann, N.C. and Zechnich, A.D. (2000) 'A randomized controlled trial to asses decay ion acquired knowledge among paramedics completing a pediatric resuscitation course', *Acad. Emerg. Med.*, 7, pp.779–786.

Sultz, H.A., Sawner, K.A. and Sherwin, F.S. (1984) 'Determining and maintaining competence: an obligation of allied health education', *J Allied Health*, 13, pp.272–279.

Tan, G.M., Ti, L.K., Suresh, S., Ho, B.S. and Lee, T.L. (2002) 'Teaching first-year medical students physiology: does human patient simulator allow more effective teaching?' *Singapore Med.J.*, 43, pp.238–242.

Taylor, H.A. and Kiser, W.R. (1998) 'Reported comfort with obstetrical emergencies before and after participation in the advanced life support in obstetrics course', *Fam. Med.*, 30, pp.103–107.

Tichon, J.G. (2002) 'Problem-based learning: a case study in providing e-health education using the interent', *J Telemed Telecare*, 8, pp.66–68.

Tollhurst, H., McMillan, J., McInerney, P. and Bernasconi, J. (1999) 'The emergency medicine training needs of rural general practitioners', *Aust. J Rural Health*, 7, pp.90–96.

Treloar, D., Beier, K.P., Freer, J., Levine, H., von Lubitz, D.K.J.E., Wilkerson, W. and Wolf, E. (2001) 'On site and distance education of emergency medicine personnel with a human patient simulator', *Mil. Med*, 166, pp.1003–1006.

Trzeciak, S., Erickson, T., Bunney, E.B. and Sloan, E.P. (2002) 'Variation in patient management based on ECG interpretation by emergency medicine and internal medicine residents', *Am. J Emerg. Med.*, 20, pp.188–195.

Tye, J.B., Hartford, C.E. and Wallace, R.B. (1978) 'Survey of continuing needs for nonemergency physicians in emergency medicine', *JACEP*, 7, pp.16–19.

Vardi, A., Levin, I., Berkenstadt, H., Hourvitz, A., Eisenkraft, A., Cohen, A. and Ziv, A. (2002) 'Simulation-based training of medical teams to manage chemical warefare casualties', *Isr. Med. Assoc. J*, 4, pp.540–544.

von Lubitz, D.K.J.E. (2002) 'EMERGENCY! Medicine and modern education technology', *Proceedings Intl. Conf. on Internet, Business, Science, and Medicine*, L'Aquila, August 2002, CD-ROM, SSGRR (L'Aquila), ISBN 88-85280-63-3.

von Lubitz, D.K.J.E., Carrasco, B., Fausone, C.A., Gabbrielli, F., Kirk, J., Lary, M.J., Levine, H., Patricelli, F., Pletcher, T.A., Stevens, G. and Wroblewski, G. (2004) 'Bioterrorism: development of a large-scale medical readiness using multipoint distance-based simulation training', in J.D. Wood, R.S. Haluck, H.M. Hoffman, G.T. Mogel, R. Phillips and R.A. Robb (Eds) *Building a Better You – The Next Tools for Medical Education, Diagnosis, and Care, Medicine Meets Virtual Reality 12* (Studies in Technology and Informatics, 98), Amsterdam: IOS Press pp.221–227.

von Lubitz, D.K.J.E., Carrasco, B., Gabbrielli, F., Levine, H., Levine, R., Ludwig, T. and Poirier, C. (2003) 'Transatlantic medical education: preliminary data on distance-based high fidelity human patient simulation training', in J. Westwood (Ed.) *Medicine Meets Virtual Reality*, Amsterdam: IOS Press, pp.379–385.

von Lubitz, D.K.J.E., Freer, J., French, A., Hawayek, J., Montgomery, J., Levine, H. and Wolf, E.. (2001) 'Autostereoscopy in medical telepresence: the Medical Readiness Trainer experience', in F. Patricelli and P.K. Ray (Eds) *Proceedings of HEALTHCOM 2001, 3rd Intl. Workshop on Enterprise, Networking, and Computing in Healthcare Industry*, Scuola Superiore G. Reiss Romoli, L'Aquila, Italy, June 29–July 2001, pp.61–76, ISBN 88-85280-53-6.

von Lubitz, D.K.J.E., Levine, H. and Wolf, E. 2002) 'The goose, the gander, or the Strasbourg paté for all: medical education, world, and the internet', in W. Chin, F. Poatricelli and V. Milutinovic (Eds) *Electronic Business and Education: Recent Advances in Internet Infrastructures*, Boston: Kluwer Acad. Publ., pp.189–210.

von Lubitz, D.K.J.E., Montgomery, J. and Russell, W. (2000) 'Just in time training: emergency medicine training aboard a ship'. *Navy Medicine*, 3–4, pp.24–28.

von Lubitz, D.K.J.E., Pletcher, T., Treloar, D., Wilkerson, W. and Wolf, E. (2000) 'Immersive virtual reality platform for medical training: a 'killer application'', in J. Williams et al. (Eds) *Medicine Meets Virtual Reality*, Amsterdam: IOS Press, pp.207–213.

von Lubitz, D.K.J.E..and the MRT Team (2000b) 'Medicine in the village: technology, health, and the world', in B. Vlasovic, A. Cesar, R. Meolic and F.S. Balan (Eds) *IEEE Proc.* '*Conf. on Extra skills for Young Engineers*' *Symposium*, Maribor: Maribor University Press, pp.27–33.

Watterson, A.E. and Thomas, H.F. (1992) 'Acute pesticide poisoning in the UK and information and training needs of general practitioners recording a conundrum', *Public Health*, 106, pp.473–480.

Watterson, L., Flanagan, B., Donovan, B. and Robinson, B. (2000) 'Anaesthetic simulators: training for the broader health-care profession', *Aust. N.Z. J. Surg.*, 70, pp.735–737.

Watterson, L., Flanagan, B., Donovan, B. and Robinson, B. (2000) 'Anaesthetic simulators: training for the broader care health-care profession', *Aust. N.Z. J. Surg.*, 70, pp.735–737.

Weller, J.M., Bloch, M., Young, S., Maze, M., Oyesola, S., Wyner, J., Dob, D., Haire, K., Durbridge, J., Walker, T. and Newble, D. (2003) 'Evaluation of high fidelity human patient simulator in assessment of performance of anaesthetists', *Br. J. Anaesth.*, 90, pp.43–47.

West, H. (2000) 'Basic infant life support: retention of knowledge and skill', *Paediatr. Nurs.*, 12, pp.34–37.

Willaims, B. (2001) 'Bioterrorism: are we prepared?', *Tenn. Med.*, 94, pp.413–417.

Williams, K.A., Rose, W.D. and Simon, R. (1999) 'Teamwork in emergency medical services', *Air Med. J*, 18, pp.149–153.

Wise, A.L., Hays, R.B., Adkins, P.B., Craig, M.L., Mahoney, M.D., Sheehan, M., Siskind, V. and Nichols, A. (1994) 'Training for rural general practice', *Med. J Aust.*, 161, pp.314–318.

Wong, S.H., Ng, K.F. and Chen, P.P. (2002) 'The application of clinical simulation in crisis management training', *Hong Kong Med. J*, 8, pp.131–135.

Zack, J.E., Garrison, T., Trovillion, E., Clinkscale, D., Coopersmith, C.M., Fraser, V.J., Kollef, M.H. (2002) 'Effect of an education aimed at reducing the occurrence of ventilator-associated pneumonia', *Crit. Care Med.*, 30, pp.2407–2412.

Zautcke, J.L., Lee, R.W. and Ethington, N.A. (1987) 'Paramedic skill decay', *J Emerg. Med.*, 5, pp.505–512.

Notes

1 http://www.flightofthephoenix.org/link_trainer.htm